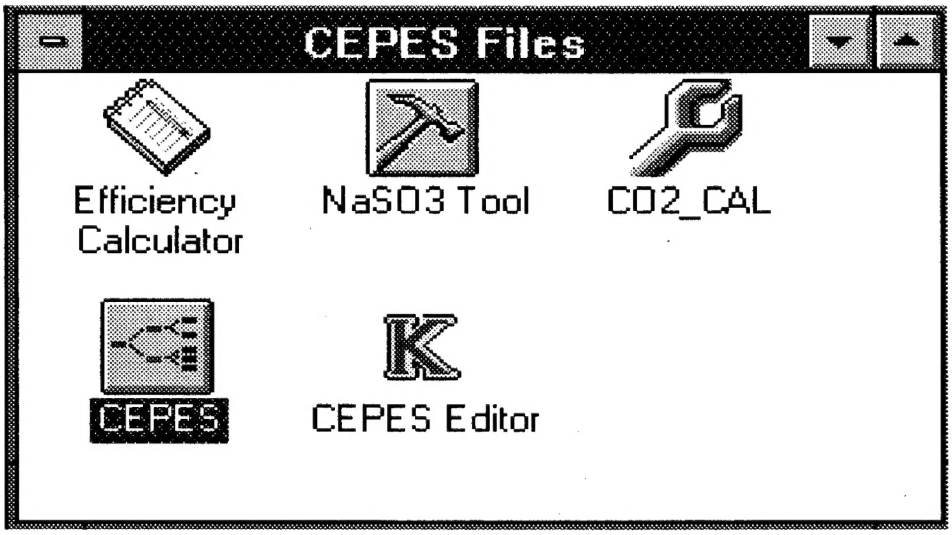
US Army Corps
of Engineers
Construction Engineering
Research Laboratories

USACERL ADP Report-95/04
June 1995

Coal-Fired Central Energy Plant Operations Expert System and Editor (CEPES Version 4.3 and CEPES Editor Version 2.4) User's Guide

by
Ralph Moshage, Tony Magliero, Mike Brewer, Bob Lorand, Madhavi Kantameni, and Todd Blindt



Rising operation and maintenance (O&M) costs of central heating plants have forced the Army to seek alternative methods of running these facilities. Computer technology offers a great potential to automate and assist in many O&M tasks by helping diagnose equipment malfunctions and failures. An automated diagnostic tool for coal-fired heating plant equipment could reduce the demand for human labor and free personnel for higher priority work, reduce downtime for repair, promote thermal efficiency, and improve on-line reliability.

Researchers in this project developed a coal-fired central energy plant operations expert system (CEPES), which analyzes and recommends solutions to coal-fired boiler operational problems. This phase of the project included the selection of hardware and software platforms, development and coding of the expert system, and knowledge acquisition for one module for field testing. The design of CEPES is unique because of the development of a system editor (CEPES Editor) that allows a field engineer to construct a plant configuration and insert expertise without the use of source level code.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 1995	Final

4. TITLE AND SUBTITLE
Coal-Fired Central Energy Plant Operations Expert System and Editor (CEPES Version 4.3 and CEPES Editor Version 2.4) User's Guide

5. FUNDING NUMBERS
MIPR
W56HZV89AC01

6. AUTHOR(S)
Ralph Moshage, Tony Magliero, Mike Brewer, Bob Lorand, Madhavi Kantameni, and Todd Blindt

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Construction Engineering Research Laboratories (USACERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ADP-95/04

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Center for Public Works (USACPW)
ATTN: CECPW-EM
7701 Telegraph Road
Alexandria, VA 22310-3860

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Rising operation and maintenance (O&M) costs of central heating plants have forced the Army to seek alternative methods of running these facilities. Computer technology offers a great potential to automate and assist in many O&M tasks by helping diagnose equipment malfunctions and failures. An automated diagnostic tool for coal-fired heating plant equipment could reduce the demand for human labor, freeing personnel for higher priority work; reduce downtime for repair; promote thermal efficiency; and improve on-line reliability.

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14. SUBJECT TERMS
central heating plants
boilers
expert systems
Central Energy Plant Operations Experts System (CEPES)

15. NUMBER OF PAGES
52

16. PRICE CODE

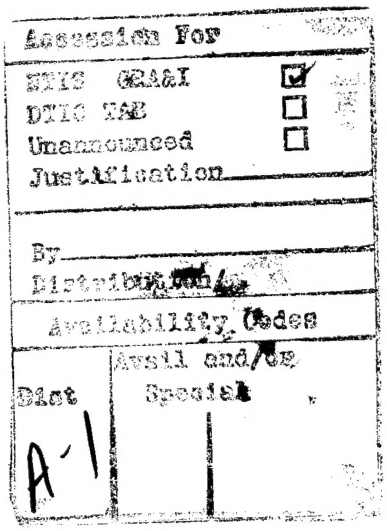
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

Foreword

This study was conducted for the U.S. Army Center for Public Works (USACPW) under Military Interdepartmental Purchase Request (MIPR) No. W56HZV89AC01. The technical monitor was John Lanzarone, CECPW-EM.

The work was performed by the Utilities Division (UL-U), Utility and Industrial Operations Laboratory (UL), U.S. Army Construction Engineering Research Laboratories (USACERL). This research was supported in part by an appointment to the Research Participation Program at USACERL administered by the Oak Ridge Institute for Science and Education (ORISE) through an interagency agreement between the U.S. Department of Energy and USACERL. Special appreciation is expressed to the public works staff at Rock Island Arsenal, Rock Island, IL, and the staff and management at Abbott Power Plant, University of Illinois, Champaign, IL, for their participation in the software testing program. Martin J. Savoie is Acting Chief, CECER-UL-U, John T. Bandy is Operations Chief, CECER-UL, and Gary Schanche is Chief, CECER-UL. The USACERL technical editor was Agnes E. Dillon, Information Management Office.

LTC David J. Rehbein is Commander and Acting Director of USACERL. Dr. Michael J. O'Connor is Technical Director.



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1 Introduction

Background

Science Applications International Corporation (SAIC), under the sponsorship of the U.S. Army Construction Engineering Laboratory (USACERL), has developed a trouble-shooting guide (TSG) for distinguishing between problems caused by operational procedures or equipment deficiencies versus problems caused by inadequate coal quality. Although the TSG presents sufficient information for diagnosing many central plant problems, an expert system that incorporates this information and additional information relating to noncoal quality based operational and equipment problems would have even greater utility to a plant.

There have been many advances in the development and use of expert systems in recent years. Expert systems can provide on-line, convenient access to knowledge. In this project, SAIC developed an expert system for use by plant personnel in analyzing and solving central plant operational and coal quality problems for spreader stoker-type coal plants. The starting point was the information already contained in the TSG, and additional documentation was provided by SAIC and USACERL.

The CEPES (Central Energy Plant Expert System) Editor is a companion tool to the CEPES troubleshooting software. Both CEPES and the CEPES Editor perform on PCs running Microsoft (MS)-Windows™. Both were written with KAPPA, an object-oriented programming tool sold by Intellicorp, Inc., Mountain View, CA, and both require a runtime version of KAPPA.

Objective

The overall objective of this project is to develop an expert system to help personnel at coal-fired central heating plants analyze and solve boiler operational problems. This system should provide technical support for evaluating and solving fuel and equipment-based problems resulting from incorrect operating procedures. This system also should give plant personnel appropriate technical information on coal combustion processes.

The first phase of the work, covered in earlier reports (Moshage et al., August 1993, December 1993), involved: (1) selection of the hardware and software platform, (2) development of the expert system structure, (3) investigation of knowledge engineering, and (4) coding of the expert system.

The second phase of the project involved the improvement of the software architecture, imbedding of coal technology information, and beta testing of the completed program.

Approach

Because CEPES is a relatively small software project, it was considered preferable to use commercially available expert programing tools instead of developing a source code. Additionally, to allow field users to imbed information and modify logic, a CEPES Editor was developed. The CEPES Editor gives the user the opportunity to improve the accuracy of the CEPES program and tailor the program to actual site equipment configurations without the services of a computer programmer.

CEPES and CEPES Editor were developed incrementally with modules and features being developed and tested separately before being combined into a larger working unit. The incremental approach gave the developers flexibility to take advantage of improvements to commercially available software.

Mode of Technology Transfer

Copies of the software are available from USACERL, Utility and Industrial Operations Laboratory. The users manuals are available from USACERL or the National Technical Information Service (NTIS). Although the software is designed to allow a field engineer to install and edit, USACERL will install and edit the software to match a site's equipment on a reimbursible basis. USACERL can visit the site and imbed electronic images of local equipment as well as interview plant operators and provide computer training. A draft proposal for performing the visit is included in Appendix A.

2 Installation and Quick Start Guide

System Requirements

As a minimum, an 80286 PC with 4 MB of RAM and 25 MB of free space on the hard disk is required. The PC also will need to have VGA 256 color graphics capability with 640x480 resolution and a two-button pointing device (mouse). With the 80286 chip, the performance of CEPES will be slow, and some user frustration may be experienced. With 4 MB of RAM, memory may be exhausted if a large number of subsystems must be examined (subsystem information is loaded only as it is needed).

CEPES should be hosted on an 80486 platform with 8 MB of RAM and 30 MB free on the hard disk. Performance will be adequate on this platform, and the user will not experience any significant delays. The minimum requirement for VGA color and a two-button mouse remains unchanged with this configuration.

Installation Instructions for Editor and CEPES

The information files and programs in the CEPES and CEPES Editor disks are public domain. However, Kapparun is a proprietary program. USACERL does have an unlimited license to place it only in U.S. Army utility plants and utility-related facilities. To use the software for other applications will require the user to procure Kapparun PC 2.1.

Minimum Requirements

MS-Windows™ environment
4MB RAM (8MB recommended)
286 processor (486 recommended)
approx 20 MB hard drive space

Installation Procedure.

On your hard drive:

In the DOS environment at the root directory, make a directory\cepesw.

example: c:\md cepesw
results: c:\cepesw\

Or an easier way to make a directory is to use MS-Windows™ File Manager.

In the DOS environment, change to the cepesw directory. The file extraction must be done in the DOS environment.
Put the first floppy in the floppy drive (instructions assume it is called a:, substitute as appropriate).
Unzip the file using the -d setting to create all the directories.

ex. c:\cepesw\pkunzip -d a:\cepesw.zip
results: a lot of files and directory being inflated, about 20 MB worth.

For an explanation of the directory and file nomenclature, see Appendix C.
The unzip routine will give you some instructions about putting in the last disk.

Now launch windows to load Kapparun.
Go to the main program window.
Put the floppy labeled Kapparun in the floppy drive a: (if not already done).
Pull down the files menu and click on the "Run..." option.
In the run command line box type:

a:setup (if the floppy is in drive a:. Substitute drive name as appropriate).

This will start the Kapparun installation. Choose the default directory name suggestions.
When the install program asks for a choice between the full development version or just the executable installation, choose the second option, installing only the executables. If you chose the wrong option, nothing is damaged and the setup will stop.

The installation will add a line to your autoexec.bat file.

Now exit windows and reboot your computer for all the changes to take effect.

Launch the windows environment again.
Go to the Kapparun program window.
Go to the Files pulldown menu and click on the "New ..." selection.
Select the program item selection.
In the Properties window (Figure 1) enter the following in the information boxes:

Command Line: c:\kapparun\kapparun c:\cepesw\cepes.bin
Name: CEPES
Working Directory: c:\cepesw

Click on the Change icon button.
Select the icon that represents a gray flow chart.
Click OK.
Click OK in the property window.

A program item named CEPES should appear.
Go to the Files pulldown menu and click on the "New ..." selection.
Select the program item selection.
In the Properties window (Figure 2) enter the following in the information boxes:

Name: CEPES Editor
Command Line: c:\kapparun\kapparun c:\cepesw\editor.bin
Working Directory: c:\cepesw

Click on the Change icon button.
Select the icon that represents a large K.
Click OK.
Click OK in the property window.
A program item named CEPES Editor should appear.

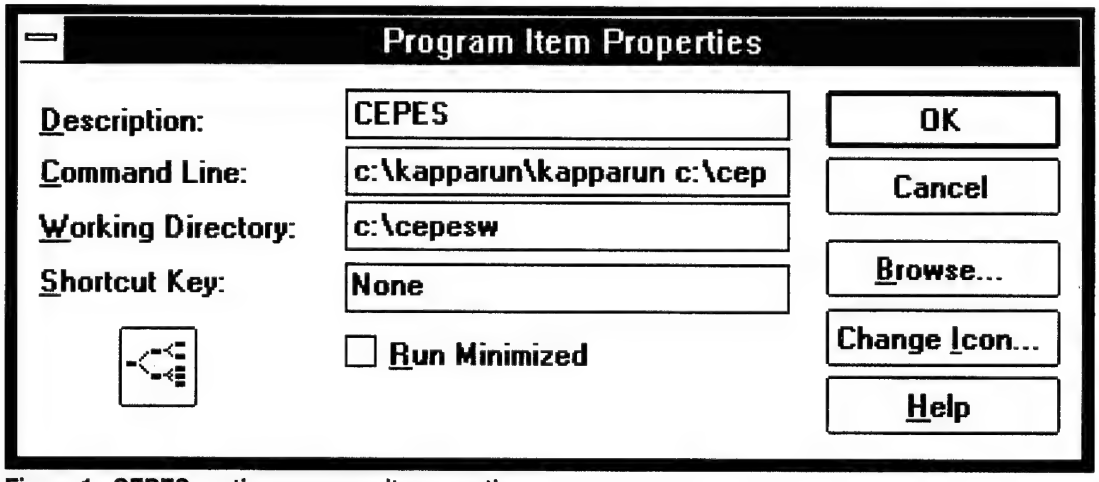

Figure 1. CEPES runtime program item creation.

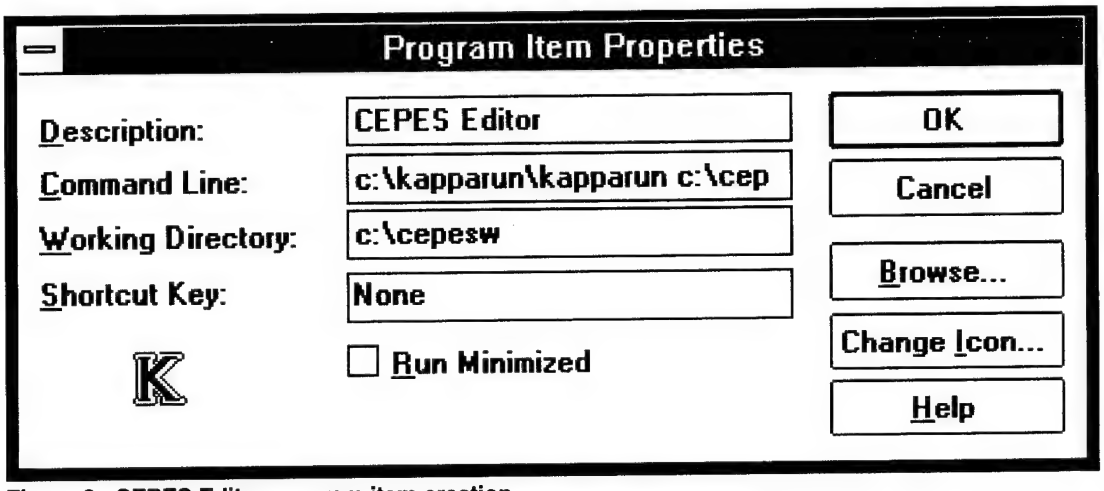

Figure 2. CEPES Editor program item creation.

There should now be two new program items in the KAPPA-PC program group (Figure 3). To launch CEPES, click on its icon (Figure 3).

A menu window will appear (Figure 4). In the center window move the highlight bar to the directory named c:\cepesw\runtime and double-click the left mouse button. In the right window, which lists the files, highlight the file named RIA1.KAL (or any other .KAL file in that directory) and click with the left mouse button.
Click the OK button.

It may take 60 to 90 seconds to get all the programs loaded.

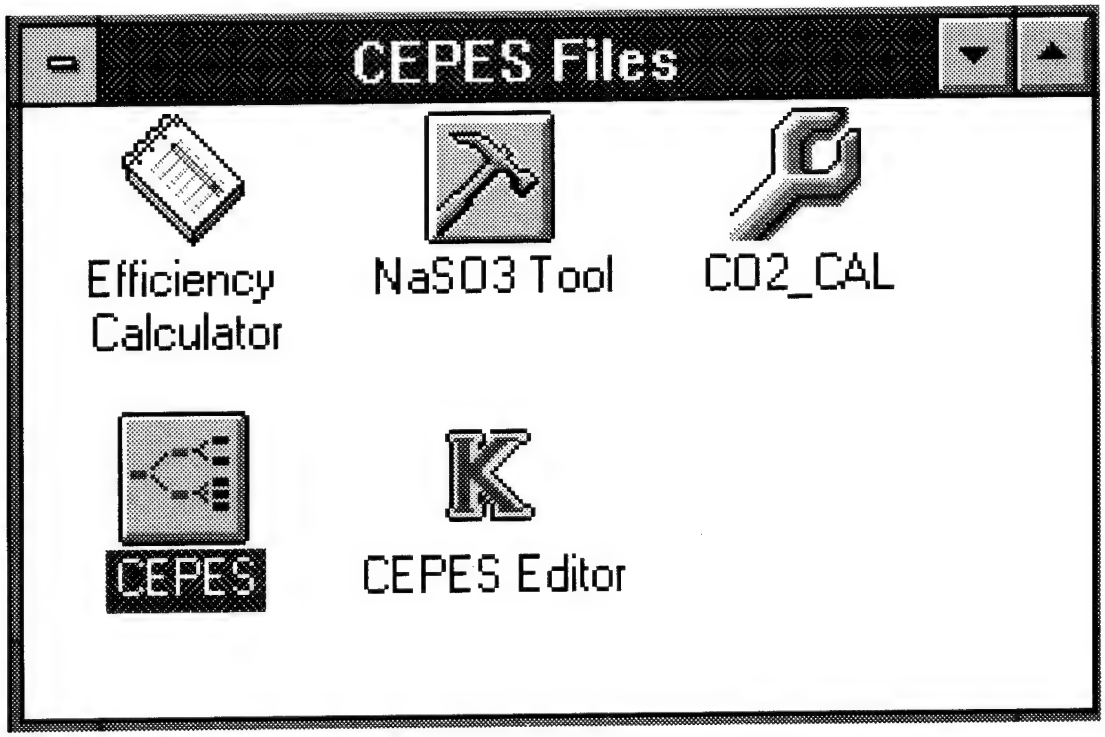

Figure 3. CEPES files program group.

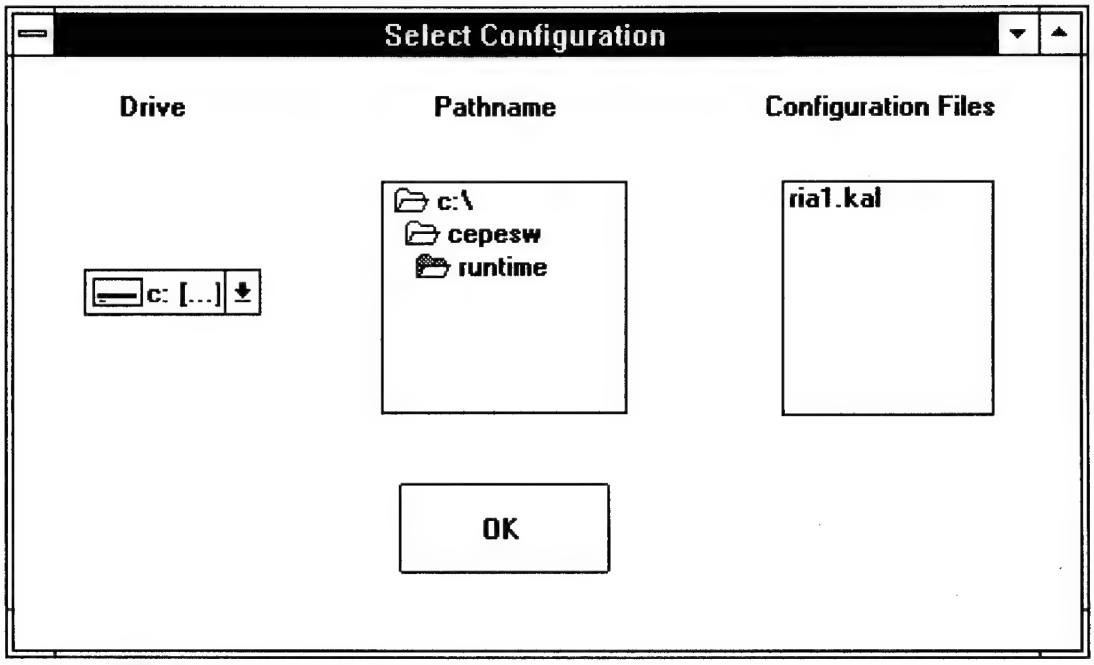

Figure 4. CEPES runtime file selection menu.

CEPES is durable and allows the user to use either mouse button. However, if it is a MS-Windows™ looking feature, use the left mouse button as required by MS-Windows™. At the main screen click on a box of interest, and the program will take you to its subordinate objects. One difference in CEPES is that the QUIT button means quit the whole program. In Editor, QUIT means close that screen. To backtrack or go to a different screen, click the HISTORY button and choose where to go.

The color of the buttons has meaning. Yellow means an object is related to another object that is out of specification or malfunctioning. You should look at those objects to see if they need attention too. Red means something is wrong in that object, and green means a user has looked at that object and corrected the maligned condition or the condition is satisfactory. The red and green colors are durable in that they will not change if a related object is changed; this means that, if you actually correct a condition to green but find another problem in a related object, the program will not turn the green object back to yellow for reinvestigation. This seems reasonable because the primary function of CEPES is to direct the troubleshooting so all plausible causes and effects are looked at one time and judged as being pertinent or not.

After quiting CEPES, you can launch CEPES Editor from its icon.

It may take 60 to 90 seconds to get all the programs loaded.

In CEPES Editor, many of the non-MS-Windows™ buttons use the right mouse button. With the right mouse button, click LOAD CONFIGURATION. CEPES Editor is like a blank sheet of paper. You could model anything that is systematic in nature. However, start with one of the installed configurations or load the default configuration.

A menu will pop up. Choose a configuration with the left mouse button.

Watch for the hourglass icon to turn back to an arrow. It may take 2 to 3 minutes. When the arrow reappears, look in the lower right hand portion of the screen for the words "config: <name of configuration>".

You can click and look as you desire inside the configuration. The only caution is that you must use the quit buttons on the screen to maneuver. Do not use the MS-Window™ pull down menus or Alt-Tab to navigate.

If you want to keep some changes, you must do the SAVE AS in the main screen. This will make a working configuration you can edit later and allows you to leave unconnected objects when you quit.

If you want to make a CEPES runtime model, do the SAVE AS CEPES RUNTIME in the main screen. The program will check for unconnected objects that would crash the CEPES program. If the program discovers unconnected objects it will alert you. At the end of the process, a message window will appear to give you the option of purging the unconnected objects or cancelling the save procedure. If you cancel, you can manually connect or delete those objects. You must use the main screen DELETE SUBSYSTEM or SYSTEM or COMPONENT buttons to delete those objects. The delete functions in the EDIT TOP LEVEL, EDIT SYSTEM, or EDIT SUBSYSTEM windows will not completely remove an object.

The CEPES Editor is a powerful tool. You can demonstrate this by allowing a plant engineer to build an expert system without having to work in C++, LISP, or any of the other higher level AI languages. However, to achieve this functionality within the resource constraints, some prudence is required on the part of the engineer who is building a system. Because the program will allow linking of objects in long causality chains across many systems, the potential exists for the engineer to model a closed loop. The CEPES program will fail upon entering a closed loop. The CEPES Editor will trap the loops for the engineer, but some causal relationships actually are circular. The engineer will have to intelligently choose where to break the loop and make a note in the description file to inform the user of the circular causality.

3 User's Guide to CEPES and System Documentation

CEPES Overview

In CEPES, the spreader stoker plant is broken down into at least five systems (water treatment, coal handling, boiler, solid waste, and pollution control). Some of the configurations may have more systems if electrical generation equipment is present. Each of these systems is further broken down into subsystems such as coal bunker (coal handling), fly ash handling (solid waste), and multicyclone (pollution control). For each subsystem, CEPES contains a number of problems associated with that subsystem. Some subsystems may be broken down further into components that will contain the problems associated with that component. All systems, subsystems, components, and problems are represented by rectangular images that are mouse sensitive. By positioning the mouse's pointer over a rectangle and depressing either mouse button, users can access the appropriate information.

The bottom most node in the configuration description, whether it is a component or subsystem, is where the user makes a judgment about plant conditions and symptoms. As an example, Figure 5 shows the screen for the bucket conveyor subsystem. The structure of the screen shown in Figure 5 is based on the procedures listed in the coal TSG. The right side blocks identify the subsystem problems. The left side blocks show potential causes that may reside in that subsystem. It was assumed in the TSG that the operators will first notice the problem then need a checklist of the diagnostic tests to discover the cause and the action that should be taken. CEPES does not make this assumption. Users are able to enter any data they wish in any order they wish. For example, operators may first notice the problem in insufficient capacity in the bucket conveyor, or they may first notice the presence of damp coal. If insufficient capacity is entered first, CEPES will direct the user to check for the presence of damp coal (among other things). If the cause damp coal is entered first, the user is warned that damp coal may lead to insufficient capacity.

In many situations, finding the problem will require the operator to inspect more than one subsystem. CEPES will allow the operator to move easily from one subsystem to another. This capability is provided by the center column in Figure 5. In this column, any other subsystem that may be linked to the problems shown on the right hand

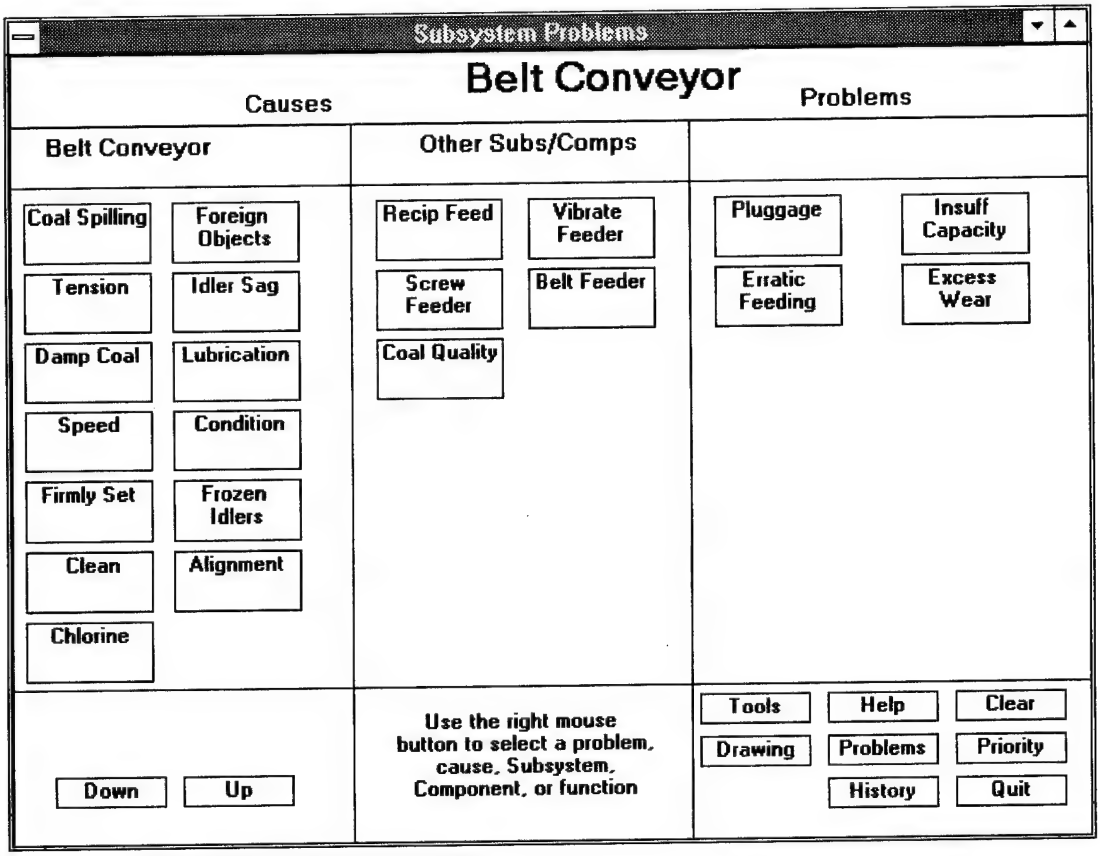

Figure 5. Typical CEPES subsystem screen.

column are displayed. By selecting these images with the mouse, the user can quickly access these subsystems.

All subsystems and problems in CEPES use color codes to indicate their status. Initially, all objects are white. When the user reports that an item is out of specification or malfunctioning, the associated rectangle becomes red; other subsystems/problems/causes that are linked become yellow. When an item is investigated and determined to be in the proper condition, the rectangle becomes green.

Using CEPES is easy. Simply select what is not proper. Those items will turn red, and all the related items will turn yellow. The yellow rectangles represent subsystems and other problems that should be investigated. By selecting the yellow rectangles, the user can track down all possible causes of a problem.

In addition to subsystems and problems, there are other function buttons in the lower right hand corner (Figure 5). These buttons are mouse sensitive and access other utilities and functions.

When a specific problem is selected from the Belt conveyor screen in Figure 5, a screen showing information about that particular problem is revealed (Figure 6). Information about the problem is displayed in the two main text screens, and function buttons are located below the text screens.

CEPES provides a final report summary of each session. This report is stored in an ASCII file with the .his extension. The report includes a listing of all the observations entered by the user, all conclusions reached by CEPES, and all correction actions reported by the user (Figure 7).

User's Guide

General Instructions

CEPES is designed to be usable for those with little previous computer skills. Little typing is required. Selecting items or answering questions is primarily done with the mouse.

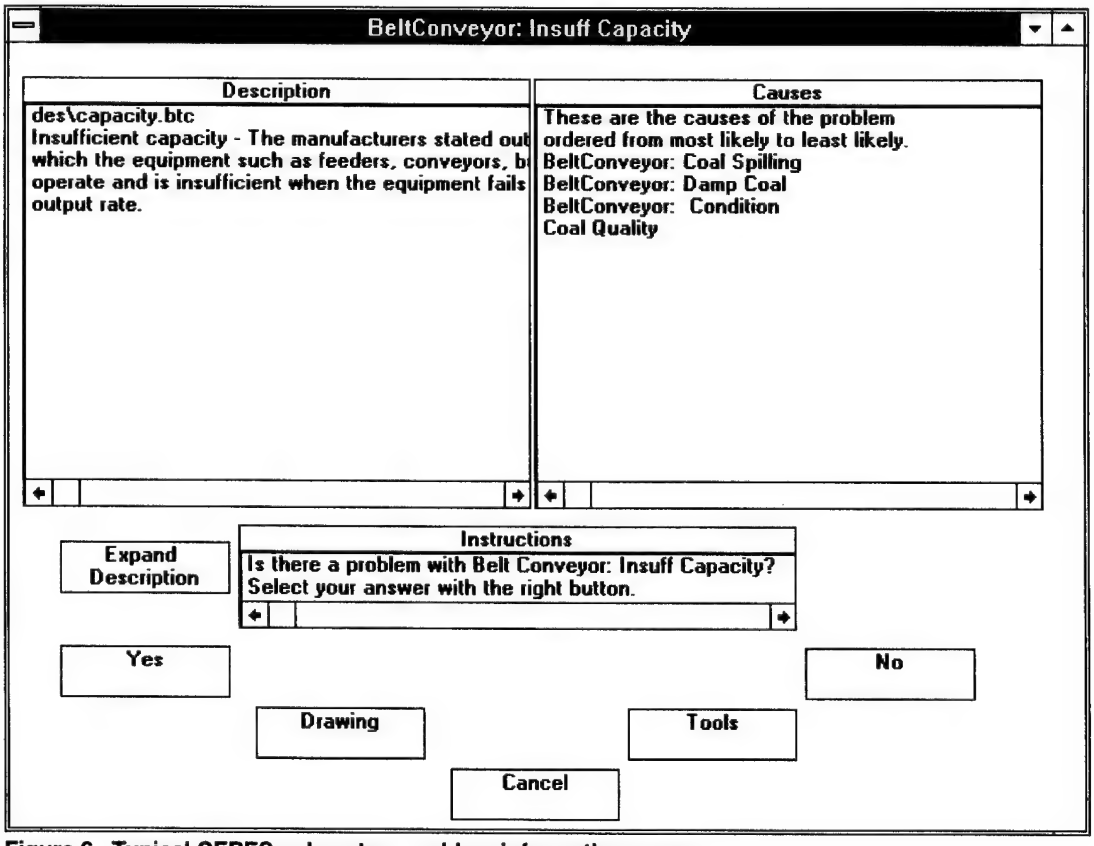

Figure 6. Typical CEPES subsystem problem information screen.

```
THIS IS THE HISTORY FILE FOR  abbott2
Date:  10/27/94
Time:  11:38:49AM
User:  mkb
Description:  NULL
**********************************************************
bspHighTDS  has been found to be bad.
fspSampleProcPoor  has been found to be bad.
fspSampleProcPoor  has received corrective action
fspSampleProcPoor  has been found to be good.
fspSampleProcPoor  has received corrective action
fspSampleProcPoor  has been found to be good.
User reports the following problem has disappeared:  High TDS in Boiler Sampling
bspHighTDS  has been found to be good.
```

Figure 7. Sample CEPES history file.

CEPES will provide on screen instructions constantly. These instructions will direct you to select something on the screen then push (click) the left or right mouse button. The program will accept use of either button when in CEPES.

Configurations

The CEPES Editor allows you to create and use different plant configurations. For example, some plants may use a vibrating feeder or a screw feeder. Some may not have an electrostatic precipitator. Each configuration must have a name given to it by the person defining the configuration. Each time you use CEPES, it will begin by asking you to select a configuration from the runtime directory.

Systems and Subsystems

In CEPES, the plant is broken down into at least five major systems; each system has a number of subsystems. These systems and subsystems are listed in Appendix B.

You can always move from one system or subsystem to another by selecting the item on the screen. If a desired item is not visible, click on the history item in the lower right hand corner. This will allow you to go to any screen you previously used. If you want to go somewhere you have not been yet in this session, select the "Systems" screen. This will allow you to choose the system and subsystem you want.

For each subsystem, CEPES engineers have defined a number of problems that can occur and the possible causes of each problem in the initial software delivery. Local plant experts can adjust the configuration using the CEPES Editor if necessary. Additionally, USACERL engineers can be asked to visit the site and tailor a configuration on a reimbursible basis (Appendix A).

Data Entry and Troubleshooting

When you select a subsystem, you will be presented with a three-column screen format (Figure 5). The right side will show problems that can be observed in a subsystem (e.g., erratic feeding, pluggage). The left side will show conditions or causes (e.g., lubrication, damp coal) in this subsystem that could produce the problems on the right. The middle column will show other subsystems that could cause the problems listed on the right (e.g., pluggage in the screw feeder may cause pluggage in the belt conveyor).

When you see something wrong in a subsystem, go to that subsystem and click on the name of the item. Follow the instructions on the screen, and answer the questions that appear in the center.

When you indicate to CEPES that something is wrong, it will change the color of the appropriate box to red. Other boxes that should be investigated will turn yellow now. If you indicate to CEPES that something is OK or within specification, it will turn that box green. This color coding will allow you to track the possible cause of a problem and which causes have been ruled out already. By simply selecting the yellow boxes (after a problem has been entered), you eventually will find the cause of a problem.

CEPES can be especially helpful when a problem in one subsystem can be caused by other subsystems. By selecting the yellow items (in any order you like) and following the instructions on the screen, you can trace problems throughout the plant and find the cause.

Function Items

CEPES has seven function items that will be seen in the lower right hand corner of the screen, although not all seven will be on the screen at all times. All items are activated by placing the mouse pointer on the item and pushing a button.

Quit: Use this item when you want to exit CEPES. When this item is selected, you will be asked to confirm that you really do want to quit.

History: Selecting this item will cause a list of screen names to appear. These are the screens you have viewed in this session. You can now move to one of these screens by placing the mouse pointer on the screen name and pushing the left mouse button. This feature is especially useful when you are going back and forth between subsystems.

Priority: CEPES engineers have stored an order for investigating the causes of a problem. This order can be adjusted in CEPES Editor if it is inappropriate for your plant. If you want to find out what is the most likely cause of any problem, select the priority item with any mouse button.

Problem: If you are working on multiple problems, you may lose track of what has been fixed and what hasn't been. Selecting the Problem item will produce a list of any problems you have entered into CEPES but have not found the cause of. You can now move to the screen for this problem by responding to the menu query that comes up.

Clear: If you wish to reset CEPES item colors, position the mouse pointer over this item and click. This function item will reset all red, yellow, and green items back to white.

Help: Selecting this item will produce a help message.

Drawing: Selecting this item will display a bitmap drawing associated with the active subsystem or problem. A message will be posted if no drawing is available.

Tool: The selection of this item will activate an external executable program associated with the active subsystem or problem.

4 User's Guide to CEPES Editor and System Documentation

The CEPES Editor is a companion tool to the CEPES troubleshooting software. Both CEPES and the CEPES Editor perform on PCs running MS-Windows™. Both were written with KappaPC 2.1, an object-oriented programming tool sold by Intellicorp, Inc., Mountain View, CA, and both require a runtime version of KappaPC 2.1.

Figure 8 shows the relationship between CEPES and CEPES Editor. The two tools are linked by configurations that are ASCII files describing the systems, subsystems, components, and problems associated with a particular plant. The CEPES Editor loads a configuration and allows the user to edit and save a configuration. CEPES reads in a configuration and controls the troubleshooting of the configuration. CEPES is not allowed to change a configuration.

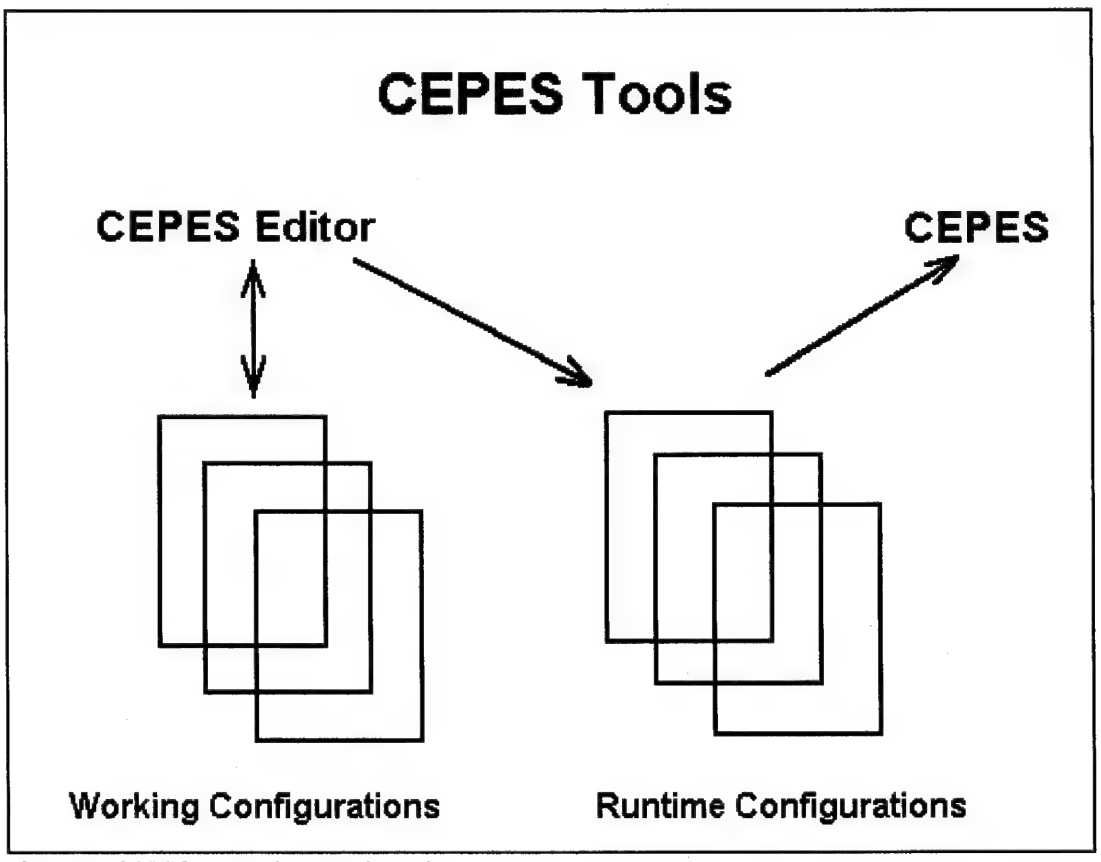

Figure 8. CEPES and Editor relationship.

The CEPES Editor provides all of the capabilities needed to construct a complete CEPES application. It provides a WYSIWYG (what you see is what you get) capability for making connection diagrams of systems, subsystems, and components. It allows problems to be linked and unlinked within and across subsystems and components and for priorities to be assigned to causes of a problem.

Because both tools use the same model of a configuration, they share a common object model. Figure 9 shows a subset of this model. The top node is called CepesThings because all of the configuration-related information is stored beneath it. Beneath CepesThings is Structures. The Structures node is so named because it is believed that the objects beneath it will represent actual physical structures in a configuration. Structures is broken down to Systems and SmallStructures. SmallStructures is broken down into SubSystems and Components. Beneath Systems, SubSystems, and Components are the individual objects for a configuration (e.g., CoalHandling, Condensate, Pumps). All configurations are automatically provided with a Coal-Quality subsystem that cannot be deleted and often is treated as a special case in both CEPES and the CEPES Editor.

All subsystems (except the special case CoalQuality) can be broken down into components or they can have problems directly associated with them, but not both. Breaking a subsystem down into components then associating problems with the components allows for a fine grain analysis of a configuration while attaching the problems directly to the subsystem provides a less-detailed viewpoint.

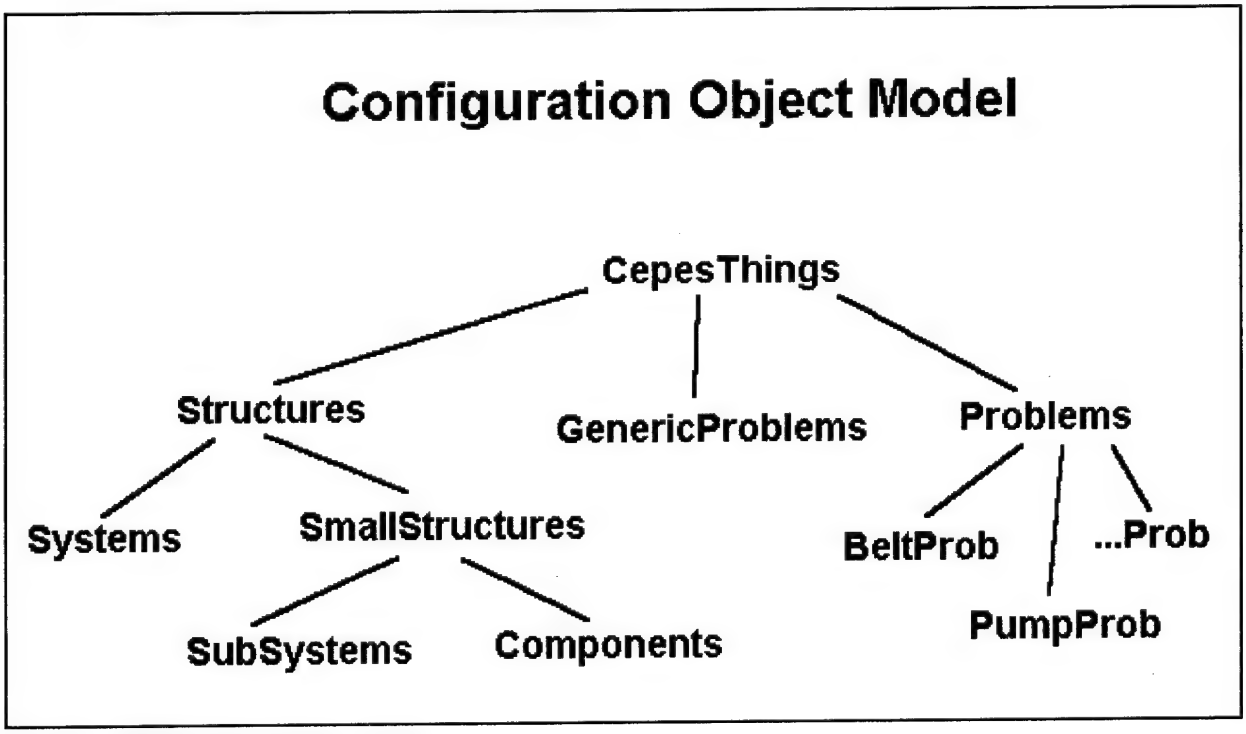

Figure 9. CEPES configuration model.

Another node directly beneath CepesThings is called GenericProblems. This node is found only in the CEPES Editor. All of the problems addressed in the original CEPES are beneath this node. These problems are captured here without any reference to subsystems or components, e.g., Pluggage and DampCoal are GenericProblems, not bltPluggage (for the Belt subsystem) or cbkDampCoal (for the Coal Bunker).

Under the Problems node, a node for each configuration subsystem (with problems attached) and component is generated. For example, if a configuration contained a Belt subsystem (with no components) and a Pump component, there would be a BeltProb and PumpProb node generated under the Problems node. Individual problems for each subsystem and component are now stored under the appropriate node. Thus, bltPluggage is placed under BeltProb and pmpSqueak (Pump Squeak) is placed under PumpProb.

As a CEPES Editor user attaches a problem with a subsystem or component, copies of a GenericProblem are made and placed under the appropriate Problems node. If the user wishes to create a problem that is not already in the GenericProblems class, the CEPES Editor first generates a new GenericProblem then places a copy of it under the appropriate Problems node. This minimizes the keying in of redundant information for problems that occur in multiple subsystems or components.

The CEPES Editor has 11 screens. From the main screen, the user can move to six different kinds of edits. From a subsystem or component, the user can move to the editing of a specific problem. From the problem edit screen, users may move to screens that draw the cause-and-effect relationships of problems in graphical form. Note that users cannot move directly from the main screen to a problem edit. Rather, they must navigate through the structure to which the problem belongs.

This remainder of this chapter is structured around the CEPES Editor screens. All of the screens adhere to a few, simple principles. Each screen contains a row of blue buttons on the bottom that are activated by a mouse click. These buttons are known as function buttons. One of these buttons is always a help button that provides a screen-specific help message. In addition to the blue buttons, the CEPES objects (i.e., Systems, SubSystems, Components, and Problems) themselves are mouse sensitive and will react differently to a mouse button click. The Help button for each screen will describe these features. Because the Help button is self-explanatory, it is not described in the following sections.

Frequently, the CEPES Editor will ask questions with a number of choices appearing in the center of the screen. These menu selections are always made by using the left mouse button, as is the convention with MS-Windows™ .

Main Screen

The Main Screen contains function buttons and edit/create buttons (Figure 10). The edit/create buttons are centered and are green. The function buttons are on the bottom and are blue.

Function Buttons

The Editor has six function buttons at the bottom of the main screen.

Load Defaults: Loads the default file containing the Systems, SubSystems, and Problems defined in the Phase 1 CEPES. Note: There are no components in the defaults, and the problems in the defaults are unlinked.

Load Configuration: Loads a CEPES Editor configuration with a user-defined name.

Save Configuration: Saves a CEPES Editor configuration with a user-defined name. This configuration may be loaded in the future for further editing.

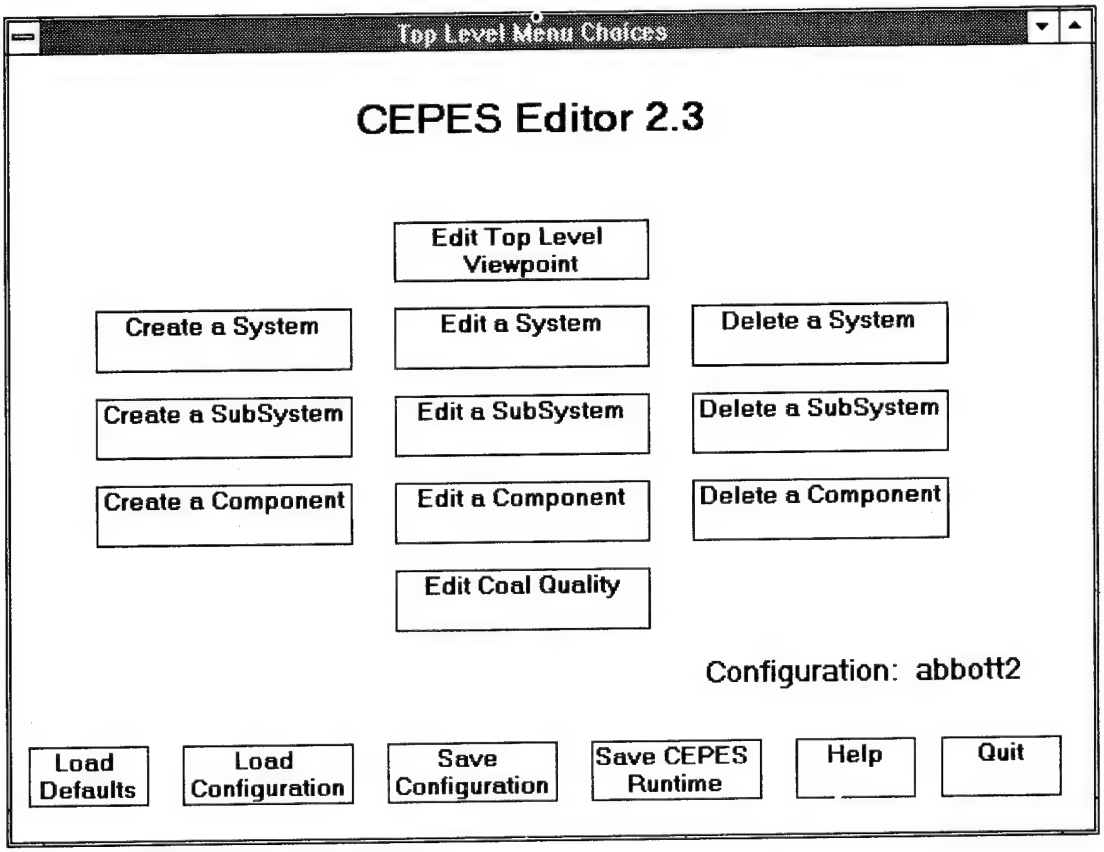

Figure 10. CEPES Editor main screen.

Save CEPES Runtime: Generates a CEPES-ready configuration and places it in the \runtime directory. Configurations saved by "Save Configuration" are not yet CEPES-compatible and are considered to be only working copies.

Quit: Exits the Editor and returns the user to MS-Windows™.

CEPES-ready configurations must be in proper form before they are stored. All subsystems must belong to a system and all components must belong to a subsystem. The CEPES Editor will check for "unattached" subsystems and components whenever a CEPES-ready save is requested. If unattached objects are found, the user must either agree to their deletion before the CEPES-ready save is performed or abort the save.

Because CEPES uses some bitmap objects not used by the CEPES Editor, the "Save CEPES Runtime" button automatically generates these objects and saves them as part of the CEPES-ready configuration.

Edit/Create Buttons

The CEPES Editor main screen has 11 editing buttons in the middle of the screen (Figure 10).

Edit Top Level Viewpoint: Allows the user to edit the overall viewpoint (system connection diagram) of the configuration.

Edit a System: Allows the user to edit a specific system.

Edit a SubSystem: Allows the user to edit a specific subsystem.

Edit a Component: Allows the user to edit a specific component.

Edit Coal Quality: Allows the user to edit coal quality.

Create a System: Allows the user to create a system.

Create a SubSystem: Allows the user to create a subsystem.

Create a Component: Allows the user to create a component.

Delete a System: Deletes a system and all references to it in a configuration.

Delete a SubSystem: Deletes a subsystem and all references to it in a configuration.

Delete a Component: Deletes a component and all references to it in a configuration.

The create functions can be invoked from both the main screen and appropriate places in the individual edit screens. Similarly, delete function buttons are found throughout the CEPES Editor. The delete buttons from the main screen remove CEPES objects totally from the configuration model. In contrast, the Delete a SubSystem button on the Edit a System screen and the Delete a Component button on the Edit a SubSystem with Components screen only separate the object from the larger structure to which it is attached.

Edit Top Level

The Edit Top Level screen displays the systems in the configuration and allows the users to format the top level viewpoint that will be observed by CEPES users (Figure 11). The systems are mouse sensitive. With a click of the left button, you can drag a system to a new location. A click of the right button allows you to connect or disconnect two systems.

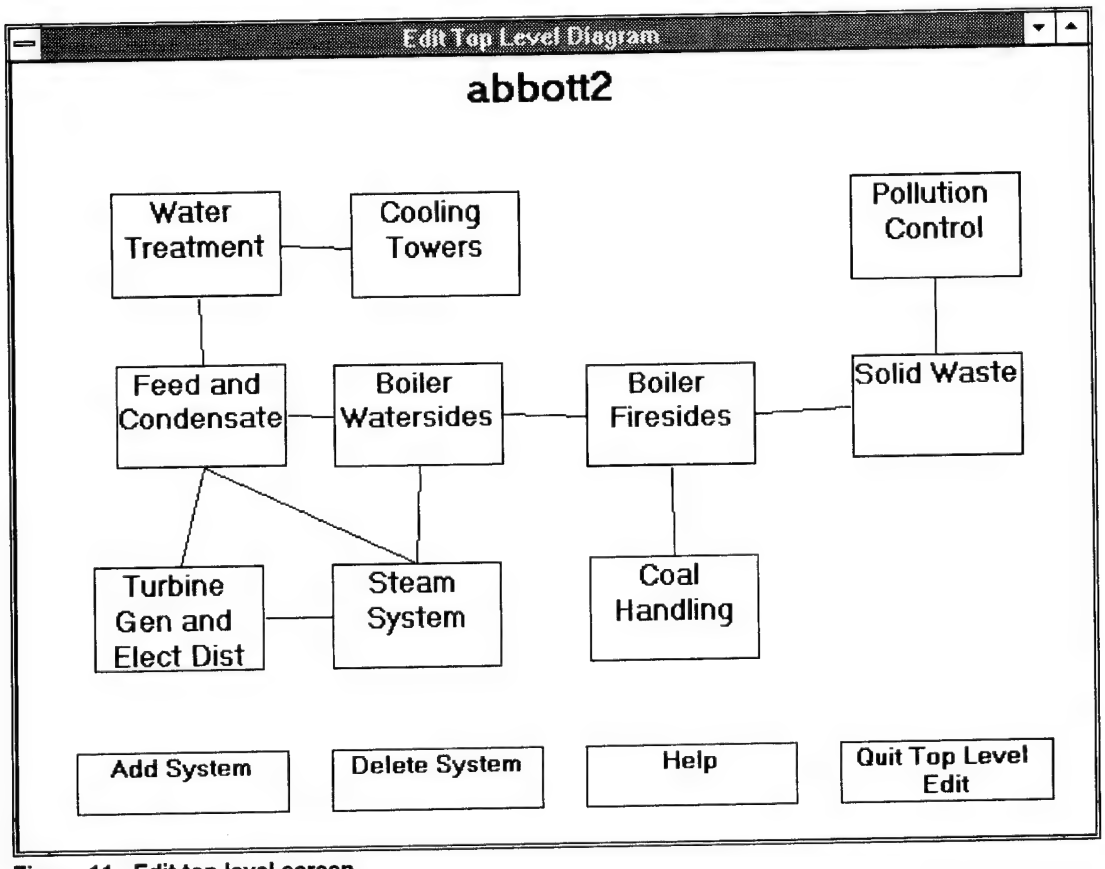

Figure 11. Edit top level screen.

The Edit Top Level screen has four function buttons at the bottom of the screen.

Add System: This buttons adds a system to the configuration.

Delete System: This button deletes a system from the configuration.

Quit Top Level Edit: This button hides the Edit Top Level screen and returns the user to the main screen.

Edit System Screen

The Edit System screen displays the subsystems for a system (Figure 12). The subsystems are mouse sensitive. With a click of the left button you can drag a subsystem to a new location. A click of the right button allows you to connect or disconnect two subsystems.

The Edit System screen has five function buttons at the bottom of the screen.

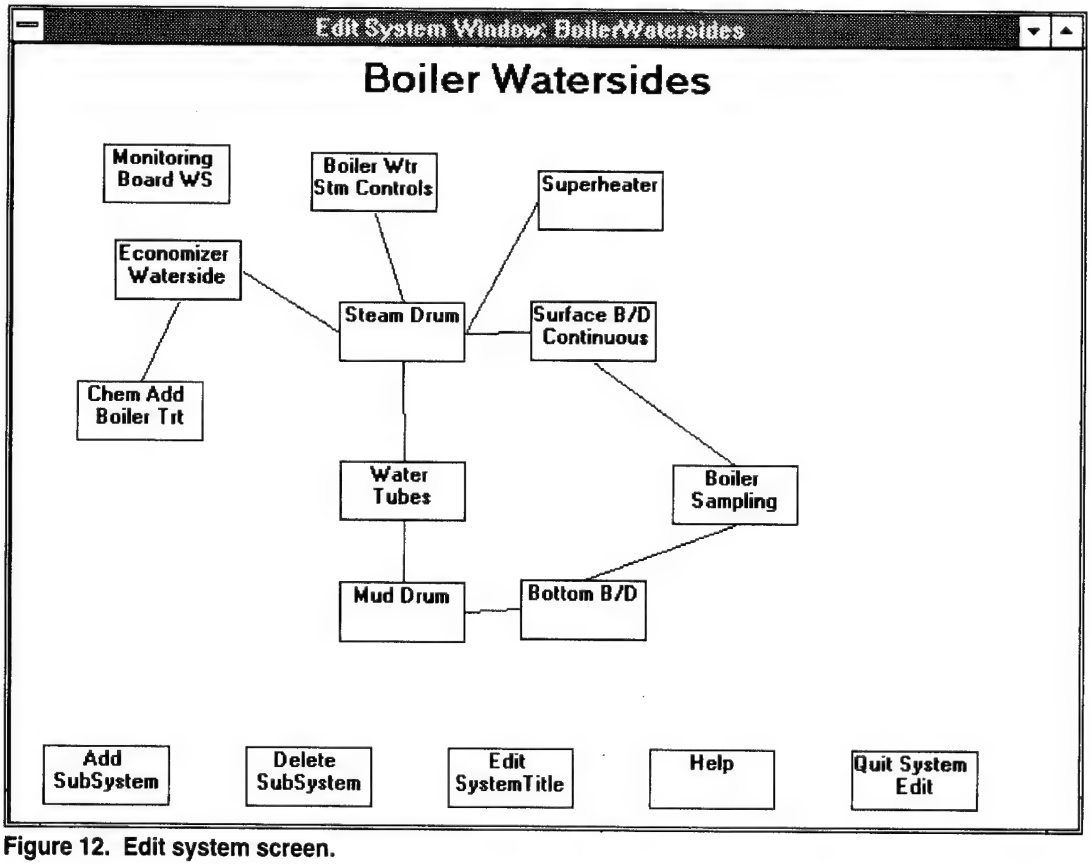

Figure 12. Edit system screen.

Add SubSystem: Allows the user to add a subsystem to a system. If the subsystem to be added does not exist, the user can create a new subsystem from this menu. Subsystems can be associated with only one system. Thus, subsystems in other systems will not appear in the menu options here. To move a subsystem from one system to another, it is necessary to disassociate the subsystem from the original system (see Delete SubSystem) before adding it to the new system.

Delete SubSystem: Allows the user to delete a subsystem from a system. The subsystem does not completely disappear from the configuration, it is just disassociated from this system.

Edit System Title: Allows the user to change the title of a system without changing the name of the actual object.

Quit System Edit: Returns to the main menu.

Edit SubSystem with Problems Screen and Edit Component Screen

The Edit SubSystem with Problems and Edit Component screens are almost equivalent and will be described together. The screen will display the problems associated with the appropriate subsystem or component (Figure 13). Unlinked problems will

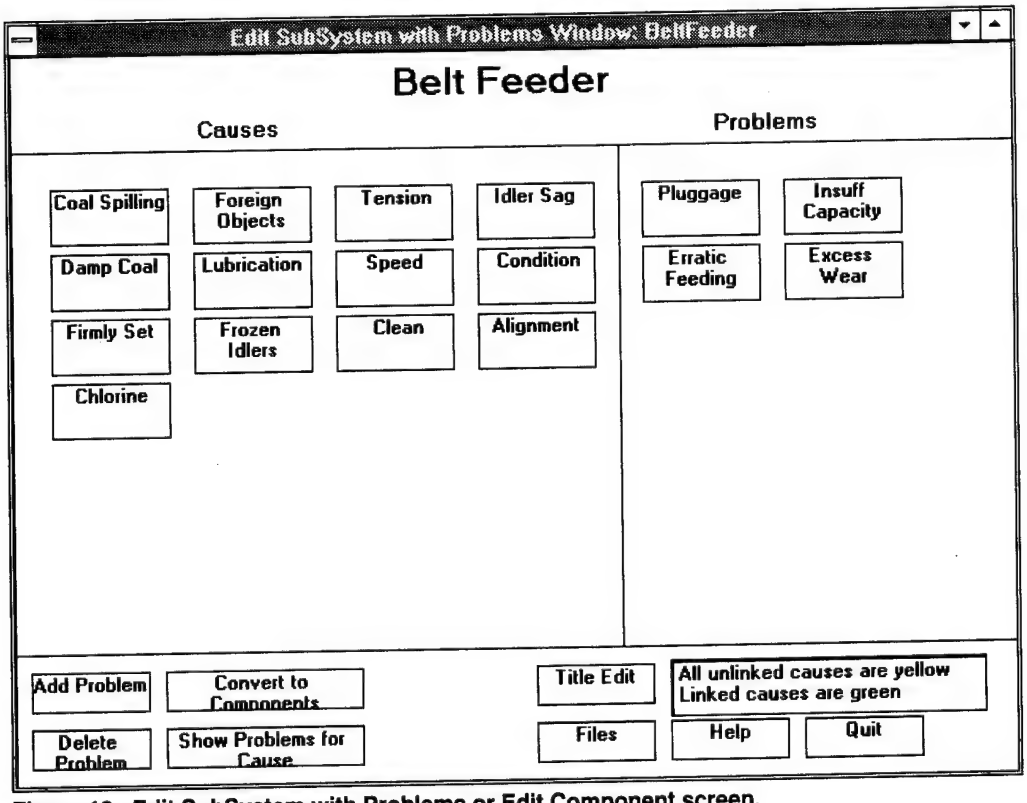

Figure 13. Edit SubSystem with Problems or Edit Component screen.

appear yellow, and linked problems will appear green. Problems can be linked to problems in the same subsystem or component, and they can be linked to problems in other subsystems or components. Problem linking and unlinking is performed in the edit problem screen and is described in the next section.

Problems in a subsystem or component are displayed in two groups. Problems that have had local causes identified will appear on the right side; a local cause is defined as a cause that is in the same subsystem or component. All other problems and causes appear on the left side. For example, bltPluggage (Belt Pluggage) is caused by bltDampCoal (Belt DampCoal); in this instance both problems are said to be linked and both will now appear green. Because a local cause has been identified for bltPluggage, it will now appear in the right column and bltDampCoal will remain in the left column.

All problems can be edited. A click on the problem from the right mouse button will bring up a summary about how the problem is currently being used (e.g., local problem, nonlocal cause) and a prompt asking the user how the object is to be edited (i.e., as a cause, as a problem). The answer determines whether the problem is edited in the Edit Problem screen or in the Edit Cause screen.

Problems can be linked as either a cause or an effect. For example, if problem Alpha is being edited, it may be linked to problem Beta by stating that Alpha causes Beta (in the Edit Cause screen) or by stating that Beta causes Alpha (in the Edit Problem screen).. Additonally, the CEPES Editor supports the authoring of causal chains that stay within a subsystem (or component) or move across subsystems (or components).

Up to nine function buttons are at the bottom of the screen. The up and down buttons will appear only if objects are hidden from view and need to be scrolled to be seen.

Add Problem: Allows the user to add a problem to the subsystem or component. If the proper problem does not exist, the user may create a new one here.

Delete Problem: Allows a user to delete a problem from the subsystem or component.

Convert to Components: This button appears only if a subsystem is being edited. It begins the process for converting a subsystem so it is broken down into components instead of problems. Any problems attached to the subsystem will be disassociated for the problem, and the user will be moved to the Edit SubSystem with Components screen (Figure 14).

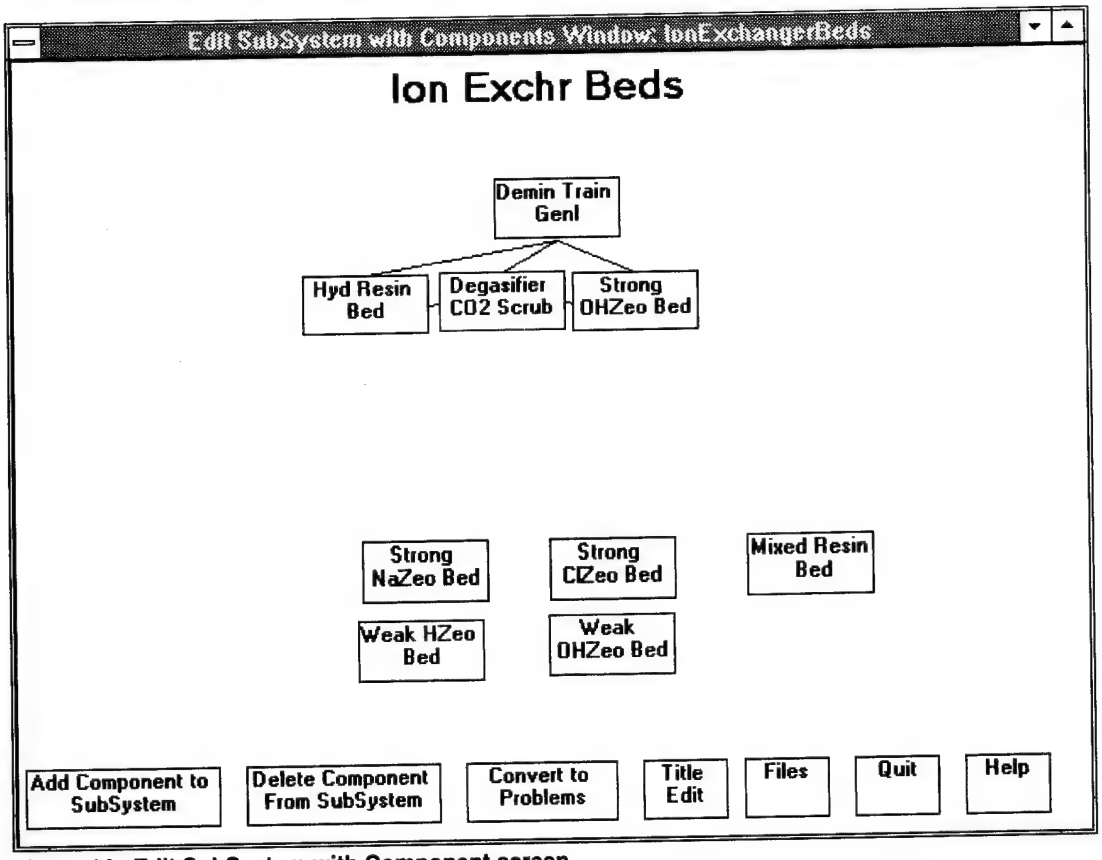

Figure 14. Edit SubSystem with Component screen.

Show Problems for Cause: Allows the user to observe the other problems that may be caused by a selected problem. Both local problems (i.e., problems belonging to the subsystem or component) and nonlocal problems (i.e., problems belonging to other subsystems and components) will be shown.

Title Edit: Allows the user to edit the title of the subsystem or component.

Files: Displays the file names used to support the subsystem or component and allows the editing of text files and the copyright notice for the subsystem or component drawing.

Quit: Returns to the main screen.

Edit SubSystem with Components

If a subsystem is broken into components, the edit screen for the subsystem will display a component connection diagram. This screen is similar to the subsystem connection diagram used for system edits (Figure 14).

The displayed components are mouse sensitive. With a click on the left button, you can drag and position a component. A click of the right button allows you to create or delete component connections.

Six function buttons are at the bottom of the Edit SubSystem with Components screen.

Add Component to the SubSystem: Allows the user to add a component to the subsystem. If the component does not exist, the user may create a new component here.

Delete Component from SubSystem: Allows the user to delete a component from the subsystem. Note that the component is still in the configuration, but it no longer is attached to the subsystem.

Convert to Problems: Users have two options for modeling subsystems. First, the subsystem can be broken into components and the problems attached to the components. Second, the subsystem can have problems directly attached to it without components. This buttons allows the user to reverse the action of the "Convert to Components" button in Figure 13. All components associated with the subsystem will be disassociated from the subsystem, and the user will be returned to the Edit SubSystem with Problems screen.

Title Edit: Allows the user to edit the title of the subsystem.

Files: Shows the file names that support the subsystem and allows the editing of a copyright notice for the subsystem.

Quit: Returns the user to the main screen.

Edit Problem Screen

The Edit Problem screen displays the problem name on the top of the screen and the causes of the problem on the main part of the screen (Figure 15).

The left hand column shows the causes from the same subsystem or component (whichever the problem belongs to). The right hand column shows the other subsystems and/or components in which additional causes of the problem reside.

The Edit Problem screen is used to add or delete causes to the problem or interest. Users should note that circular causality (e.g., alpha causes beta, beta causes gamma,

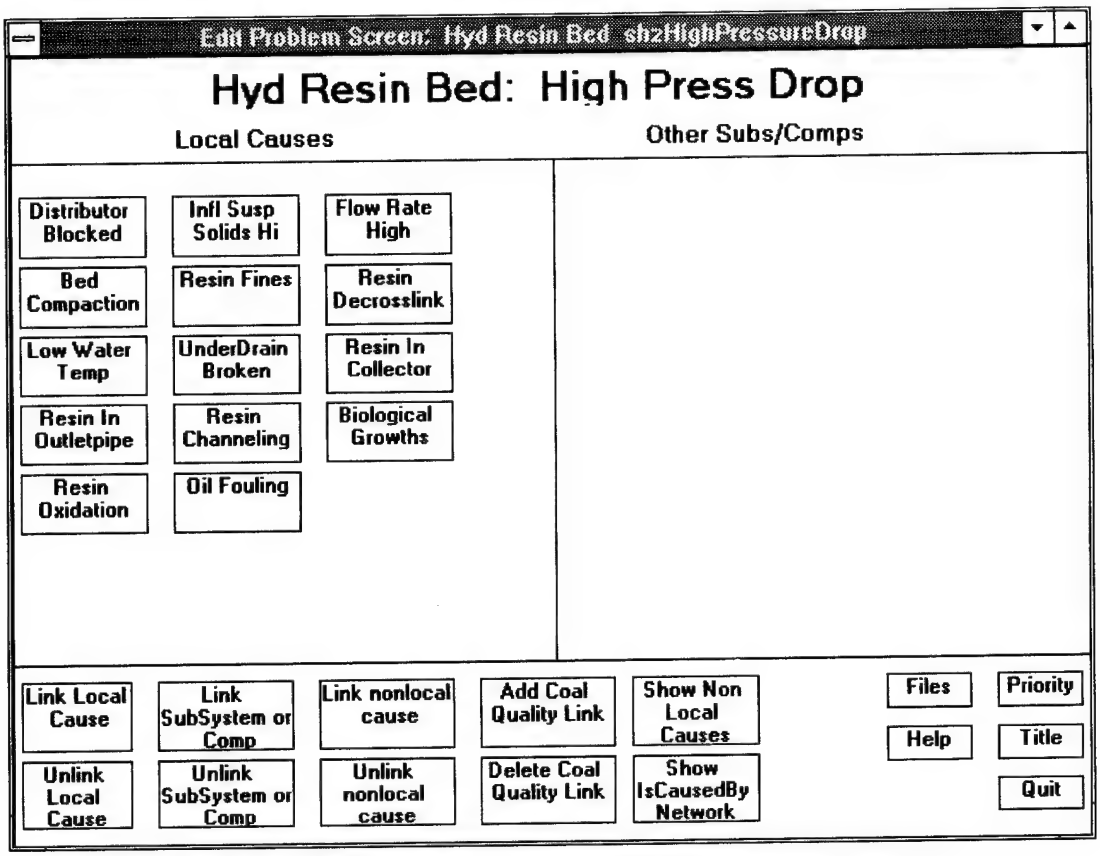

Figure 15. Edit Problems screen.

gamma causes alpha) is not allowed. Every new link is examined by the CEPES Editor. If a causal loop is formed by a new connection, the connection is not made and the user is warned.

Up to 15 function buttons are located at the bottom of the screen.

Link Local Cause: Allows the linking of a local cause to a problem. This cause is selected from a list of possible causes in the same subsystem/component as the problem being edited.

Unlink Local Cause: Allows the unlinking of a local cause.

Link SubSystem or Component: Allows the linking of another subsystem (except Coal Quality) or component to the problem.

Unlink SubSystem/Comp: Allows the unlinking of another subsystem (except Coal Quality) or component from the problem.

Link Nonlocal Cause: When a link to another subsystem or component exists, a link to a specific possible cause in that subsystem or component can be created by this button.

Unlink Nonlocal Cause: Allows for the removal of links created by the Link Nonlocal Cause button.

Add Coal Quality Link: When this button is activated, the CEPES Editor checks to see if there is any existing link between the current problem and the Coal Quality subsystem. If not, the CEPES Editor asks the user if a link to the Coal Quality subsystem should be made. If the link is already present, the CEPES Editor assumes that a link to a specific problem in Coal Quality is to be added. The user is then queried about the specific Coal Quality problem that should be added.

Delete Coal Quality Link: Activating this button gives the user the choice of removing the link to any individual Coal Quality Problem or all of the links to Coal Quality (i.e., all links to individual Coal Quality Problems and the link to the Coal Quality subsystem).

Show Nonlocal Causes: Selecting this button will display the nonlocal immediate causes for this problem.

Show Is Caused By Network: Selecting this button displays a graph showing the causality path for this problem.

Files: Displays the supporting files for the problem being edited and allows the editing of the text files and the copyright header for the problem drawing.

Priority: Allows the user to set or display the priorities for the problem being edited.

Quit: Returns the user to the edit screen for the subsystem or component to which the problem belongs.

Edit Cause Screen

The Edit Cause screen displays a cause name on the top of the screen and the problems linked to the cause on the main part of the screen (Figure 16).

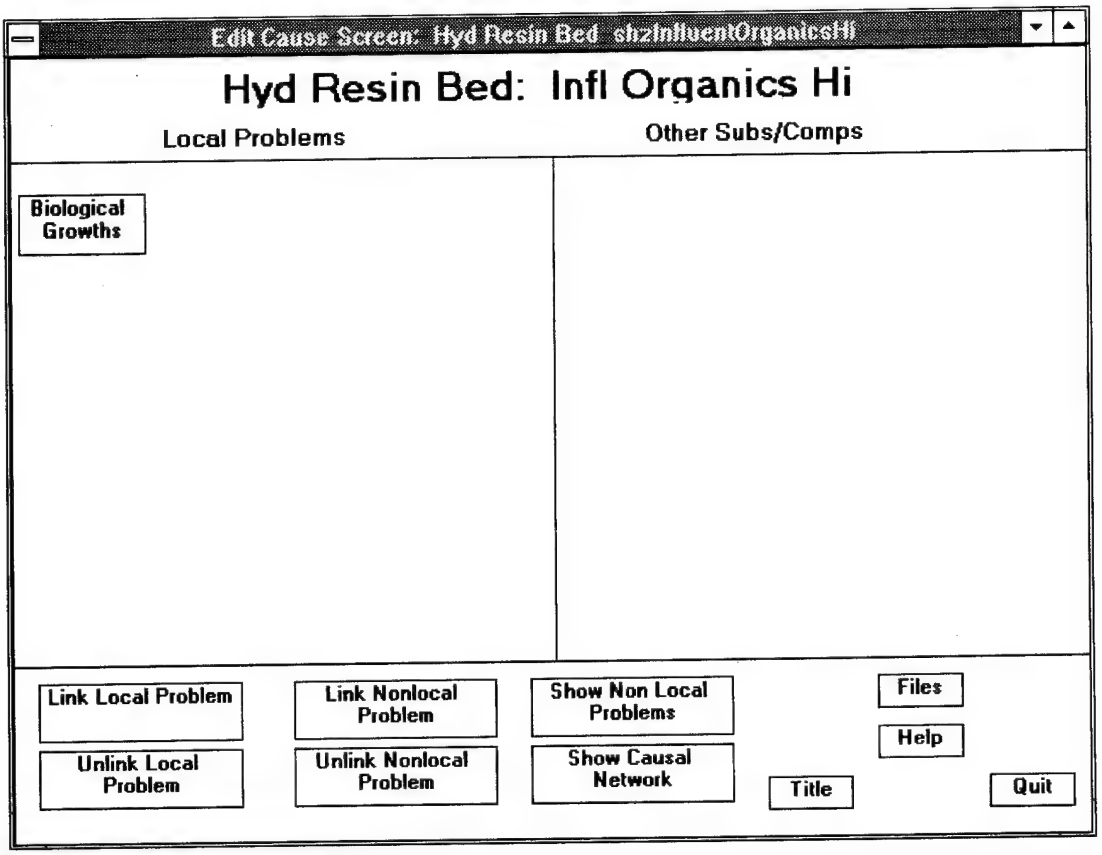

Figure 16. Edit Cause screen.

The left-hand side shows the problems from the same subsystem or component (whichever the cause belongs to). The right-hand side shows the other subsystems and/or components in which additional problems linked to the cause reside.

The Edit Cause screen is used to add or delete problems to the cause being edited. Users should note that circular causality (e.g., alpha causes beta, beta causes gamma, gamma causes alpha) is not allowed. Every new link is examined by the CEPES Editor. If a causal loop is formed by a new connection, the connection is not made and the user is warned.

Up to 12 function buttons are at the bottom of the screen.

Link Local Problem: Allows the linking of a local problem to a cause. This problem is selected from a list of problems in the same subsystem/component as the cause being edited.

Unlink Local Problem: Allows the unlinking of a local problem.

Link Nonlocal Problem: Allows the linking of a problem in another subsystem or component to the cause.

Unlink Nonlocal Problem: Allows the unlinking of a problem in another subsystem or component from the cause.

Show Nonlocal Problems: Selecting this button will result in the display of the specific problems in another subsystem or component that are linked to this cause.

Show Causal Network: Selecting this button displays a graph showing the causality path that originates at this cause.

Title: Allows the user to edit the title of the cause.

Files: Displays the supporting files for the problem being edited and allows the editing of the text files and the copyright header for the problem drawing.

Priority: Allows the user to set or display the priorities for the problem being edited.

Quit: Returns the user to the edit screen for the subsystem or component to which the problem belongs.

Causal Network Screen and Is Caused By Network Screen

The Causal Network screen and the Is Caused By Network screens are similar and will be discussed together. They display graphical line drawings of the cause-and-effect relationships among problems; the causes are shown on the left and the effects are shown on the right.

In the Causal Network, the selected problem is shown on the far left and the effects resulting from it are shown branching to the right (Figure 17).

In the Is Caused By Network screen, the selected problem is shown on the far right and the causes leading to it are shown branching to the left (Figure 18).

Only five function buttons are on these screens. The Up, Down, Left, and Right buttons all scroll the network in the appropriate direction; the Quit button returns the user to the Edit Problem or Edit Cause screen (whichever is appropriate).

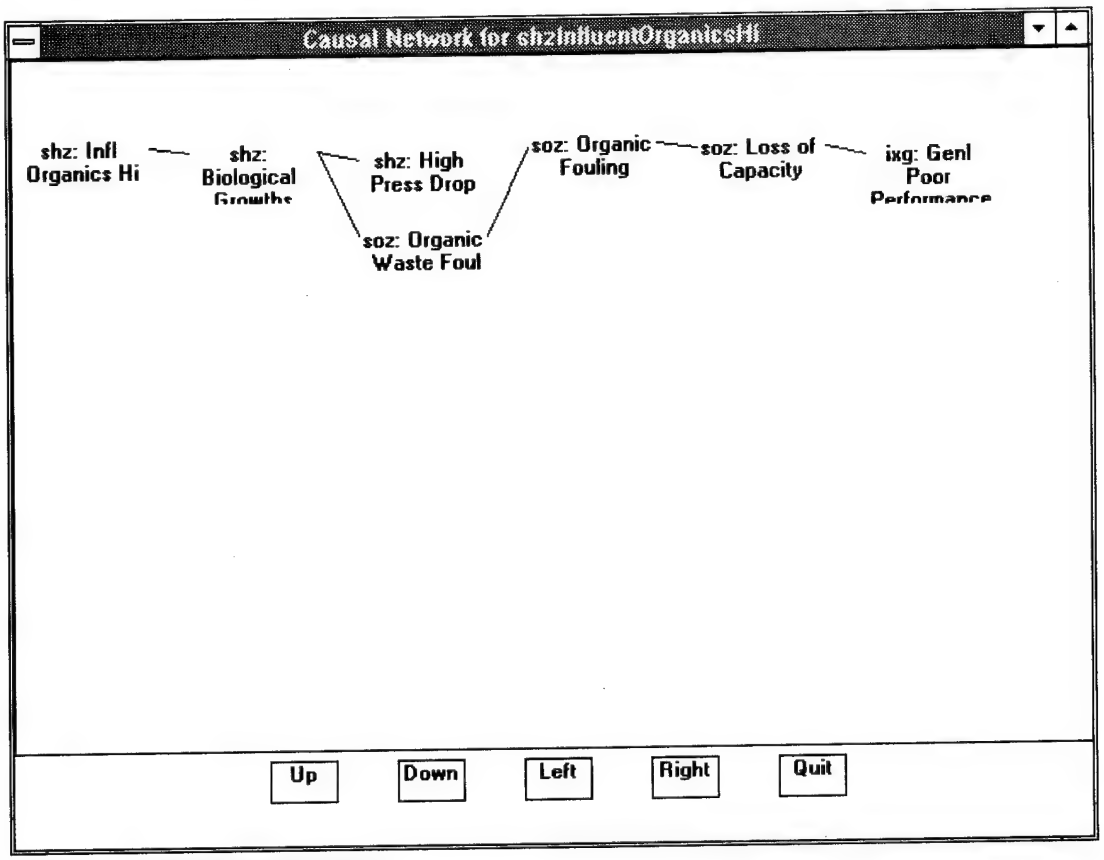

Figure 17. Causal Network screen.

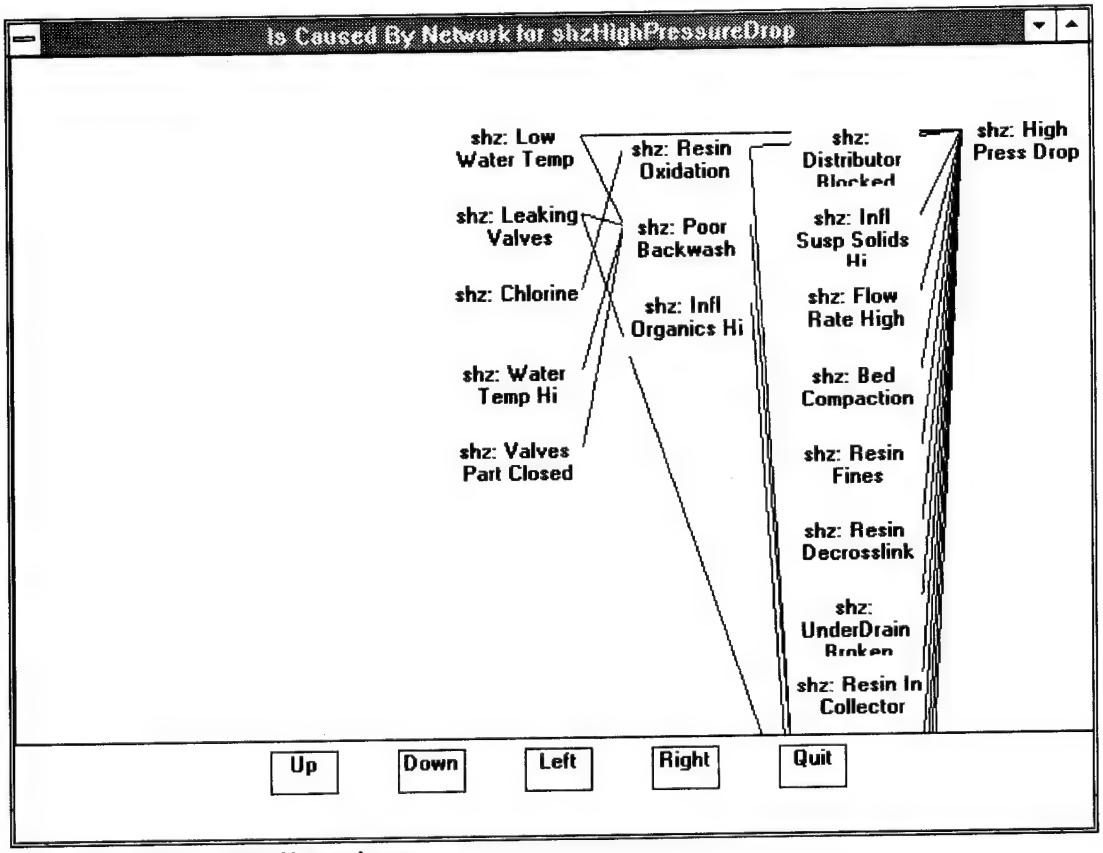

Figure 18. Is Caused By Network screen.

Edit Coal Quality

The Edit Coal Quality screen (Figure 19) is somewhat similar to the screen for editing a subsystem with problems. It displays the problems in Coal Quality. The individual Coal Quality problems are mouse sensitive, and selecting them will invoke the Edit Cause screen for that problem. Note: Because Coal Quality problems only are allowed to cause other problems and cannot be caused by other problems, the Edit Problem screen cannot be called with Coal Quality problems.

Up to eight function buttons are at the bottom of the screen.

Add Problem: Allows the addition of a new problem to Coal Quality. If the appropriate problem does not exist, the user may create a new one here.

Delete Problem: Allows the deletion of a problem from Coal Quality.

Edit Problem Title: Allows the user to edit the title of any problem in Coal Quality.

Show Problems for Cause: Displays problems in other subsystems or components that have a Coal Quality problem linked to them.

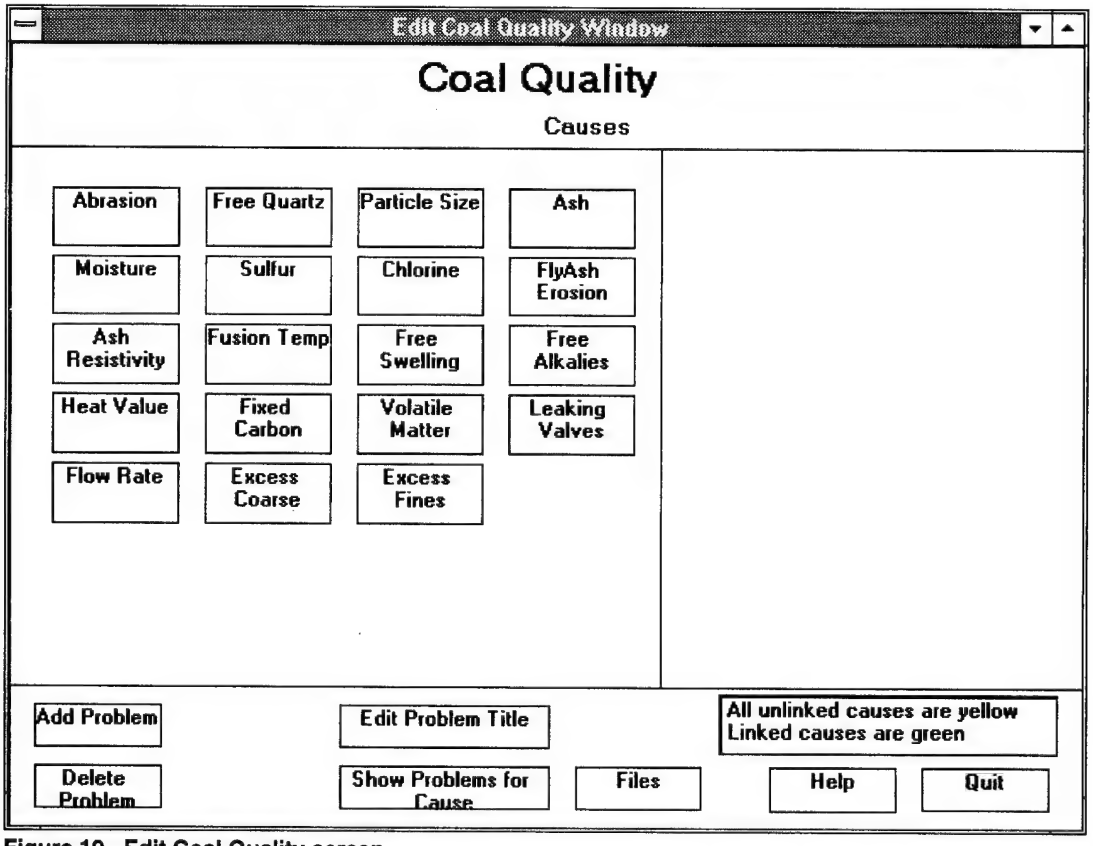

Figure 19. Edit Coal Quality screen.

Files: Displays supporting file names for any Coal Quality problem and allows the editing of the text files and the copyright headers for the problem drawings. Note that the user must select a subsystem or component here because Coal Quality problems have different documentation for each subsystem or component.

Quit: Returns the user to the main screen.

References

Moshage, R., T. Magliero, R. Lorand, M. Kantamneni, and T. Blindt, *Development and Use of the Coal-Fired Central Energy Plant Operations Expert System (CEPES),* Technical Report FE-93/20/ ADA273216 (U.S. Army Construction Engineering Research Laboratories [USCAERL], August 1993).

Moshage, R., M. Kantamneni, G. Schanche, M. Metea, and C. Blazek, *Application of Expert Systems for Diagnosing Equipment Failures at Central Energy Plants,* Technical Report FE-94/04/ADA276909 (USCAERL, December 1993).

Appendix A: Draft Reimbursible Proposal To Deliver a Site-Specific CEPES Configuration

TITLE: Central Energy Plant Expert System and Editor (CEPES and CEPES Editor) Site Delivery and Training Program

POC: Mike Brewer, USACERL-UL-U, 217-398-5544

DESCRIPTION:

The variety of equipment found in U.S. Army energy plants and the complexity of these plants demands that the operators be knowledgeable and highly qualified personnel. In recent years, there have been many advances in the development and use of expert systems. Expert systems can provide on-line, convenient access to knowledge. USACERL has developed an expert system for use by plant personnel in analyzing and solving central plant operational and coal quality problems for spreader stoker type coal plants. Additionally USACERL has developed a CEPES Editor as a companion tool to the CEPES troubleshooting software. Both CEPES and the CEPES Editor perform on PCs running Microsoft Windows™. Both were written with KAPPA, an object-oriented programming tool sold by Intellicorp, Inc., Mountain View, CA, and both require a runtime version of KAPPA. Although both products are simple enough to be installed and used by field personnel, USACERL is able to deliver a complete hardware, software, and training package to assist an installation in quickly constructing and using an expert system.

APPROACH:

This project will deploy an expert system in three tasks. If the site has existing hardware available for utilization by CEPES, the amount of effort for each of the tasks will need to be changed.

TASK ONE - PRELIMINARY DATA COLLECTION:

- Collect and organize plant configuration data obtained from the site by telephone, FAX, and mail.

- Imbed and tailor CEPES software based on preliminary data. Preliminary configuration should be 80 to 90% complete.
- Procure and setup CEPES hardware.
- Install and configure site-specific CEPES and CEPES Editor on procured hardware.

TASK TWO - SITE-VISIT:

- Conduct large group training on the use of CEPES and MS-Windows™.
- Install computer.
- Conduct individual training on CEPES Editor with plant engineer and other selected individuals.
- Conduct tutoring on the use of computers, CEPES, and CEPES Editor for individuals needing extra assistance.
- Take electronic photographs of equipment the site desires to imbed in CEPES.
- Edit and install electronic images in CEPES.
- Interview operators to imbed undocumented plant information.
- Collect information to be used for plant-specifice calculational tools (if applicable).
- Large group presentation on delivered and edited configuration.

TASK THREE - POSTVISIT SUPPORT:

- Provide telephonic support and tutoring to site user.
- Program and deliver plant-specific calculational tools (if applicable).

PRODUCT:

The focus of all tasks will be toward delivering CEPES and CEPES Editor to an installation equipped and trained to use the program in a sustainable fashion. The final product will be a hardware platform supporting an expert system that has been tailored to describe the configuration of a U.S. Army central energy plant.

SPECIFICATIONS:

- CEPES and CEPES Editor software
- site-specific CEPES configuration
- hardware platform to support CEPES
- training for CEPES users
- training for CEPES Editor users

- user manuals
- telephonic software support.

COST ESTIMATE: To be determined.

COMPLETION TIME:

The final task, Task Three, will be completed 2 months after the completion of Task Two. Task Two will be completed (TBD) months after the receipt of funds.

POINT OF CONTACT:

The USACERL technical points of contact for this product are Ralph Moshage and Mike Brewer, 1-800-USACERL, Ext. 5544, or 217-398-5544; e-mail, INTERNET r-moshage@cecer.army.mil or m-brewer@cecer.army.mil. The mailing address is Industrial Operations Divsion, USACERL, P.O. Box 9005, Champaign, IL 61826-9005.

Appendix B: CEPES System and SubSystem Object Names

Coal Handling System

Subsystem		Component	
ApronConveyor	apc		
ApronFeeder	apf		
BucketElevator	bce		
BucketConveyor	bkc		
BarFlightFeeder	brf		
BeltConveyor	btc		
BeltFeeder	btf		
BeltWeighScale	bws		
CoalBunker	cbk		
CoalHandlingControls	chc		
ChuteFeeder	chf		
ChuteToHopper	chh		
CoalStorage	cst		
ChuteConveyor	ctc		
DragFeeder	drf		
EnMasseConveyor	emc		
FlightConveyor	flc		
FlightFeeder	flf		
CoalHopper	hop		
PneumaticConveyor	pnc		
RecipFeed	rcp		
RedlerConveyor	rdc		
ScrewConveyor	scc		
ScrewFeeder	scf		
TripperBeltTrolley	tbt		
VibrateFeeder	vbf		
WeighLarry	whl		

Water Treatment System

Subsystem		Component	
EvaporatorMakeup	evp		
AerationFeRemoval	aer		
FiltrationSSRemoval	fss		
IonExchangeBeds	ixb	DeminTrainGeneral	ixg
IonExchangeBeds	ixb	MixedResinBed	mxb
IonExchangeBeds	ixb	StrongChlorideZeoIX	scz
IonExchangeBeds	ixb	StrongAcidIX	shz
IonExchangeBeds	ixb	StrongSodiumZeoIX	snz
IonExchangeBeds	ixb	StrongBaseIX	soz
IonExchangeBeds	ixb	WeakAcidIX	whz
IonExchangeBeds	ixb	WeakBaseIX	woz
IonExchangeBeds	ixb	DegasifierCO2Scrub	dgs
MakeupWaterTank	mwt		
RawWaterSOurce	rws		
ReverseOsmosis	rom		

Feed and Condensate System

Subsystem		Component	
ChemAddAO2Scav	caa		
CondensatePumps	cnp		
CondensateStorage	cns		
CondensatePolisher	cpo		
CondensateCoupons	crc		
CondensateReturn	crt		
CondensateSampling	csp		
Deareator	dft		
FeedPumps	fdp		
FeedwaterSampling	fsp		
HiPressFeedHeater	hph		
LoPressFeedWaterHeater	lph		

Boiler Watersides System

Subsystem		Component	
BoilerBlowdnBottom	bbd		
BoilerMonitoringBoardWS	bmw		
BoilerSampling	bsp		
BoilerWaterStmControl	bwc		
ChemAddBBoilerTreat	cab		
EconomizerWS	ecw		
MudDrumWS	mdm		
BoilerBlowdnSurfCont	sbd		
SteamDrumWS	sdm	StmDrumGageGlass	dgg
SteamDrumWS	sdm	StmDrumSafetyVlvs	dsv
SteamDrumWS	sdm	StmDrumWaterColumn	dwc
SteamDrumWS	sdm	StmDrumGenl	sdg
SteamDrumWS	sdm	StmDrumSepratrs	sds
SteamDrumWS	sdm	StmDrumWtrLevelSensor	wls
SuperheaterWS	suh		
WaterTubesWS	wtb		

Boiler Firesides System

Subsystem		Component	
AirHeater	aht		
BoilerFiresideControls	bfc		
BoilerFiresideOpsGenl	bfo		
BoilLowerFurnaceArea	blf		
BoilerMonitoringBoardFS	bmf		
DumpingGrate	dpg		
FlyAshReinject	far		
ForcedDraftFan	fdf		
FeederDistributor	fdr		
OverfireJets	oaj		
OverlapGrate	olg		
RefractorySurface	rfs		
SootBlower	stb		
TubesFireSide	tfs		
TravelGrate	trg		
VibratingGrate	vbg		

Turbine Generator and Electric Distribution System

Subsystem		Component	
TurbineGenerator1	tga		
TurbineGenerator2	tgb		
TurbineGenerator7	tgg		
TurbineGeneratorGenl	tgx		

Steam System

Subsystem		Component	
ChemAddCSteamTreat	cac		
SteamDistribution	std		
SteamLoad	stl	SteamConverterGenl	scg
SteamLoad	stl	SteamLoadGenl	sgn
SteamLoad	stl	SteamHeatersGenl	shg
SteamLoad	stl	SteamSmallTurbinesGenl	sst

Solid Waste System

Subsystem		Component	
BottomAshHandling	bah		
BottomAshSilo	bas		
FlyAshHandling	fah		
FlyAshSilo	fas		

Pollution Control System

Subsystem		Component	
Baghouse	bag		
Multicyclone	cyc		
ESP	esp		
InducedDraftFan	idf		
StackChimney	stk		

Appendix C: CEPES Directory Structure

CEPES comes with several directories and files within those directories. The cepes.bin file contains the actual binary code that is executed by the CEPES application. Beneath the main CEPES directory are the cor, des, support, coal, history, runtime, and working directories, each of which will be described.

\cor directory

This directory contains correction files, ASCII text files that define remedial actions. Each problem defined in the configuration contains a slot called CorrectionFile. The value of this slot is set to the name of a text file that describes the remedial actions associated with the problem.

All correction files are in this directory, and all are named *.# where * is the FileCode name (eight characters or less) for the problem and # is a three letter code assigned to the subsystem to which the problem belongs (see Appendix B for codes). Each problem has a unique correction file. All can be displayed by the end user.

The correction files for Coal Quality-related problems are not named as described here, and they are not stored in the cor directory. The procedures for Coal Quality corrections are described in the coal directory section.

\des directory

This directory contains description files, ASCII text files that provide descriptions of problems. Each problem defined in the configuration contains a slot called DescriptionFile. The value of this slot is set to the name of a text file that provides a description of the problem.

All description files are in this directory and all are named *.# where * is the problem FileCode and # is a three letter code assigned to the subsystem to which the problem belongs (see Appendix B). Each problem has a unique description file. All can be displayed by the end user.

The description files for Coal Quality-related problems are not named as described here, and they are not stored in the des directory. The procedures for Coal Quality descriptions are described in coal directory section.

\support directory

Each subsystem and problem in CEPES can have a bitmap drawing and an executable function associated with it. For subsystems, bitmap file names are support\#\#.bmp, and executable function file names are support\#\#.exe where # is the subsystem ThreeLetterCode. For problems, bitmap file names are support\#*.bmp and executable function file names are support\#*.exe where # represents the Three-LetterCode for the subsystem to which the problem belongs and * is the FileCode for the problem.

The exceptions to the foregoing are the executables and bitmaps for Coal Quality problems, which are described in the coal directory section.

\coal directory

The Coal Quality subsystem is a special case in CEPES and is not handled as the other subsystems are. Information about Coal Quality problems needs to be customized for each of the other subsystems. Therefore, the file names for Coal Quality information utilize the name of the operational subsystem from which Coal Quality was invoked. The file names are:

description file: coal\#*.des
correction file: coal\#*.cor
bitmap file: coal\#*.bmp
executable file: coal\#*.exe

The symbol # is the ThreeLetterCode of the immediately preceding subsystem and the * symbol is the FileCode for the Coal Quality problem. For example, if the user selects Coal Quality from the CoalBunker screen (ThreeLetterCode for CoalBunker is cbk) then selects CoalQualityAsh (FileCode = ash), the description file is coal\cbk\ash.des, and the correction file is coal\ckb\ash.cor.

\history directory

Each time CEPES is invoked, a file named *.his (where * is a user supplied name or a default name provided by CEPES) is generated and stored in this directory. This file keeps a history of all problems reported to be present or absent and all corrective

actions reported by the users. These are ASCII text files that may be viewed with an editor or printed.

\runtime directory

The runtime configuration files (*.kal), where the * is the name of a configuration, are contained in the runtime directory. These files have been checked and compiled to run when the cepes.bin program is invoked.

\working directory

The editor working configuration files (*.kal), where * is the name of a configuration, are contained in the working directory. These files are allowed to have unattached objects and cannot be used by the cepes.bin program.

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